**November 27, 2001 For Radiation, How Much Is Too Much? By GINA KOLATA**

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In their efforts to protect Americans from the hazards of radiation, federal agencies have found themselves in a quandary. People are constantly exposed to radiation from natural sources — from cosmic rays, radon seeping out of the earth and radioactive substances in soil, water, food and even from potassium in the human body itself.

Compared with this radiation, the amounts coming from human efforts like nuclear plants are, relatively, minuscule. So, the question is, How closely must this radiation be regulated?

Up to now, regulators have typically acted as if every bit of excess exposure is potentially hazardous. But some scientists question this assumption.

The issue is becoming increasingly pressing as more than 100 nuclear power plants are being relicensed so they can continue to operate. At the same time, the country faces a growing predicament of what to do with nuclear waste from power plants and weapons sites.

"The issue rages because we are regulating doses that are lower than the natural background of radiation," said Dr. Arthur Upton. A radiation expert and former director of the National Cancer Institute, Dr. Upton is a professor of environmental and community medicine at the University of Medicine and Dentistry of New Jersey.

In a report last year on radiation standards, the General Accounting Office, the investigative arm of Congress, said: "The standards administered by E.P.A. and N.R.C. to protect the public from low-level radiation exposure do not have a conclusive scientific basis, despite decades of research."

The situation is further confused, experts say, because regulatory standards are a hodgepodge.

The Environmental Protection Agency advocates a standard for all radiation exposure from a single source or site at 15 millirem a year, with no more than 4 coming from ground water. A standard chest X-ray, in comparison, gives about 10 millirem to the chest, which is equivalent to 1 or 2 millirem to the whole body. The Nuclear Regulatory Commission sets its acceptable level of radiation exposure from any one source at 25 millirem a year. In contrast, the natural level of background radiation in the United States, on average, is about 350 millirem a year, and in some areas of the country it is many times higher than that.

In New York, for example, people absorb about 100 millirem of radiation each year from cosmic rays alone, said Dr. John Boice Jr., a radiation expert, who is the scientific director of the International Epidemiology Institute in Rockville, Md. In Denver, exposure from cosmic rays averages 200 millirem a year, he said, and natural variation in radiation exposure is many times the amounts of radiation that are being disputed by regulatory agencies.

"We eat, breathe and drink low levels of radiation," Dr. Boice said.

At the same time, said Dr. Fred Mettler, chairman of the radiology department at the University of New Mexico medical school, major medical sources of radiation, like CAT scanners, have fallen outside the purview of any regulatory agency.

"A whole lot of places aren't regulated at all," Dr. Mettler said. "It's a bit of a nightmare."

"When you look at the exposure of the population from radiation, about two-thirds is due to natural background and about 15 percent is due to your friendly doctors and chiropractors," Dr. Mettler said. "Everything else is, to tell you the truth, very minimal. Less than a couple of percent is from all the nuclear reactors and all the research industry."

But, asked Dr. John Evans, a risk analyst at the Harvard School of Public Health, Why should the level of background radiation matter to the question of how much additional risk from human-generated sources is acceptable? "Why isn't the more relevant question, How much of this risk can be mitigated at what cost to you?" he asked.

The quandary over how to set radiation levels does not result from a lack of research or analysis, scientists say.

"Radiation's effects on people have been studied for over a century," Dr. Mettler said. "There's a vast literature. There are probably more studies on the harmful effects of radiation than for any other toxic or noxious agents in the environment."

And as scientists studied radiation, committees to evaluate the data proliferated.

"We have national and international standing committees that periodically review the world's literature on ionizing radiation," said Dr. Boice, who is a member of many such groups. "At the International Committee on Radiological Protection, we just celebrated our 75th anniversary and we meet two or three times a year."

Then, he said, there is the United Nations Scientific Committee on the Effects of Atomic Radiation. "That started in 1955," Dr. Boice said. "We meet every year in Vienna and we publish volumes."

In the United States, the Environmental Protection Agency, the Nuclear Regulatory Commission and the National Council on Radiation Protection and Measurements wrestle with the radiation standards question, and the National Academy of Sciences has been called upon periodically since the 1950's to weigh in with its committee, called the Biological Effects of Ionizing Radiation committee. The Department of Energy and the National Institutes of Health conduct extensive research.

The science has grown rapidly. In 1980, Dr. Boice set up the radiation epidemiology section at the National Cancer Institute with just a handful of researchers. Now, he said, while he moved on to form the International Epidemiology Institute, which conducts research for industry and the government, the cancer institute's radiation department is no longer a section, it is a branch, and one of the largest branches there, with hundreds of scientists.

"A lot of people say, `Gee, we don't know a lot about the risks of radiation,' " Dr. Boice said. "I say: `We know a whole lot. We've studied populations all over the world since the turn of the last century. We know what happens at high doses. We know what happens at medical doses. And we know that at low doses the risks are low. The controversy is just how low are they. Are they really low or are they really, really low?' "

As with other toxic substances in the environment, the stricter the standards, the more it costs to meet them.

The G.A.O. report last year, which had the subtitle "Scientific Basis Inconclusive, and E.P.A. and N.R.C. Disagreement Continues," gave some examples of the costs of complying with standards setting different levels of radiation. The cost of cleaning soil around reactors and nuclear weapons facilities could range from thousands of dollars to more than $100 million, depending on whether the standard was an exposure of 15 or 25 millirem a year, the report said.

The report said that for groundwater, the cost of going from the Nuclear Regulatory Commission's limits of 25 millirem a year to the level that the Environmental Protection Agency wants could be billions of dollars.

Scientists usually rely on a mathematical model in estimating radiation risk. The most widely used model is known as the linear-nonthreshold dose-response model. It assumes that there is no safe dose of radiation and that the risk of getting cancer or genetic damage increases along with radiation exposure.

"For better or worse, that is our model," said Stephen Page, the director of the environmental agency's office of radiation and indoor air. And with that model, he said, "the E.P.A. has tried to be as protective as possible." The agency, he added, uses that model to make sure the risk from radiation is within the allowable range from toxic chemicals, 1 in 10,000 to 1 in a million chance of developing cancer.

Some say that the linear model is the best way to estimate radiation risk, but others say that there is, in fact, a threshold below which radiation poses no hazard to health. And still others say that low doses of radiation are actually beneficial.

The linear hypothesis had its origin in 1927, when the geneticist Dr. H. J. Muller published a paper on his work eliciting gene mutations in fruit flies by bombarding them with radiation from X-rays. In a paper published in the journal Science, Dr. Muller showed that the number of mutations in fruit flies was proportional to the dose of X-rays that had struck the insects.

"He said: `Aha! There's a linear relationship,' " said Dr. Dade W. Moeller, a radiation expert and professor emeritus at Harvard who runs a consulting company, Dade Moeller & Associates in New Bern, N.C. Yet, Dr. Moeller points out, those studies by Dr. Muller used very high doses of radiation, and he elicited gene mutations, not cancer. But the idea that radiation's effects were directly proportional to its dose caught hold and soon was being used to predict cancer cases. The difficulty was in demonstrating it.

The risks of getting cancer from exposure to radiation increase with dose. But since a third of all people get cancer anyway, at some time in their lives, the problem is to find evidence that low doses of radiation cause cancers that would not have otherwise occurred. Even for people exposed to large radiation doses, like the 80,000 to 90,000 survivors of the atomic bombs exploded over Hiroshima and Nagasaki, it has been hard to find excess cancers.

"They were exposed in 1945 and nearly half are still alive," Dr. Moeller said.

Dr. Mettler said the latest data show that 12,000 of these atomic bomb survivors had died from cancer. He said the number of excess cancers in the group is about 700.

Those data, Dr. Mettler said, show that there is a small risk of cancer with an exposure of tens of thousands of millirem of radiation.

"There's a group that says that if you can't see it, it doesn't exist," Dr. Mettler said. "Then there's another group that says, `That's nice, but it doesn't mean it doesn't happen.' "

Now, some scientists even say low radiation doses may be beneficial. They theorize that these doses protect against cancer by activating cells' natural defense mechanisms. As evidence, they cite studies, like one in Canada of tuberculosis patients who had multiple chest X-rays and one of nuclear workers in the United States. The tuberculosis patients, some analyses said, had fewer cases of breast cancer than would be expected and the nuclear workers had a lower mortality rate than would be expected.

Dr. Boice said these studies were flawed by statistical pitfalls, and when a committee of the National Council on Radiation Protection and Measurement evaluated this and other studies on beneficial effects, it was not convinced. The group, headed by Dr. Upton of New Jersey, wrote that the data "do not exclude" the hypothesis. But, it added, "the prevailing evidence has generally been interpreted as insufficient to support this view."

In the meantime, the regulatory agencies are at a stalemate, continuing to disagree on radiation standards. And the committee reports and committee meetings on radiation standards go on.

A recent report, issued in June by the National Council on Radiation Protection and Risks, is 287 pages long and devoted entirely to evaluating the linear-nonthreshold model. It explains that the council "has sought to leave no significant aspect of the subject unaddressed."

Its conclusion?

For lack of a better model, it recommends keeping the linear one.

"There is not conclusive evidence on which to reject" the model, the report says, adding that "it may never be possible to prove or disprove the validity of the linear nonthreshold assumption."